



Development of a PhET-Assisted Contextual Inquiry Physics Module to Support Critical Thinking and Digital Literacy

Faiza Amalia^{1*}, Syifaul Gummah², Irham Azmi³, Fuaddunnazmi⁴

^{1,2,3,4}Physics Education Study Program, Faculty of Science, Engineering, and Applied Sciences, Universitas Pendidikan Mandalika, Mataram, Indonesia

Corresponding Author:

Author Name*: Faiza Amalia

Email*: ffaizamllya@gmail.com

Accepted: May 22th 2026. Approved: September 20th 2026. Published: September 30th 2026

ABSTRACT

Critical thinking and digital literacy are essential competencies for twenty-first-century learning, yet their development in physics education remains constrained by learning materials that do not systematically integrate scientific inquiry with digital technology. This study aimed to develop a physics module on Work and Energy using a contextual inquiry approach assisted by Physics Education Technology (PhET) simulations and to examine its validity, practicality, and changes in students' critical thinking and digital literacy following a limited implementation. The study employed a Research and Development (R&D) method using the ADDIE model, comprising analysis, design, development, implementation, and evaluation. The limited trial involved 31 Grade 10 students at SMAN 5 Mataram. Data were collected using expert-validation sheets, practicality questionnaires, a critical-thinking test, and a digital-literacy questionnaire, and were analyzed using descriptive statistics, reliability analysis, normality testing, normalized gain (N-Gain), and the Wilcoxon Signed-Rank Test. The module achieved an average validity score of 88.8% and an average practicality score of 86%. Critical-thinking scores increased from 48.2 to 82.6 with an N-Gain of 0.74, whereas digital-literacy scores increased from 46.5 to 88.9 with an N-Gain of 0.79. The Wilcoxon test indicated significant differences between pretest and posttest scores for both variables ($p < 0.001$). These findings suggest that the module has potential to support the development of critical thinking and digital literacy in a limited-trial context; however, the single-group design without a comparison group does not permit causal inference.

Keywords: physics module, contextual inquiry, PhET simulation, critical thinking, digital literacy

INTRODUCTION

Advances in science and technology in the twenty-first century have transformed the goals and practices of education. Learning is no longer expected to focus solely on the acquisition of factual knowledge and conceptual mastery, but also on the development of competencies that enable students to respond to increasingly complex academic, social, and technological challenges. Among these competencies, critical thinking and digital literacy are particularly important because students are increasingly required to interpret information, evaluate evidence, make reasoned judgments, and use digital resources responsibly. Critical thinking enables learners to analyze information, examine relationships among variables, evaluate the credibility of evidence, formulate explanations, and draw logical conclusions. Digital literacy, meanwhile, involves the ability to access, understand, use, and evaluate information delivered through digital technologies [1], [2]. In contemporary learning environments, these competencies are closely related because students frequently encounter scientific information through digital media and must determine how such information can be interpreted and used

appropriately. In physics education, this requirement becomes even more important because meaningful learning depends not only on understanding scientific concepts, but also on the ability to analyze evidence, interpret representations, and make decisions based on reliable information.

Physics is a discipline that combines conceptual understanding, mathematical reasoning, empirical evidence, and the interpretation of phenomena. However, many physics concepts are abstract and cannot always be observed directly in conventional classroom settings. Concepts involving changes in energy, relationships among physical variables, or interactions between forces and motion may be difficult for students to understand when learning relies primarily on verbal explanation and mathematical equations. Digital technology can therefore provide important support by enabling students to visualize scientific phenomena, interact with representations, and explore relationships that would otherwise remain abstract. Digitally integrated physics learning resources have been reported to support students' critical-thinking skills [4]. Technology-supported learning also provides opportunities for students to access, manage,

interpret, and evaluate information more independently [5]. Nevertheless, the educational value of technology depends on how it is incorporated into the learning process. Technology is more meaningful when it does not merely function as a medium for displaying content, but becomes part of activities that require investigation, reasoning, interpretation of evidence, and evidence-based decision making.

One digital resource with substantial relevance to physics learning is the Physics Education Technology (PhET) simulation. PhET simulations provide interactive environments in which students can manipulate variables, observe changes in real time, repeat experiments, and examine relationships among physical quantities that may be difficult to investigate directly in a conventional classroom [7], [20]. Such characteristics make PhET particularly useful for learning physics because students can move beyond passively receiving explanations and instead explore how changes in one variable affect other variables. Previous studies have shown that integrating PhET simulations with inquiry-based learning can facilitate conceptual exploration and increase student involvement in the learning process [7]. The use of digital access features in physics modules also demonstrates the potential for connecting printed or structured instructional materials with online learning resources. For example, contextual physics modules integrated with QR-code access can provide students with direct pathways to digital learning resources [6]. These developments suggest that digital simulations can be more pedagogically meaningful when they are embedded within a structured learning design that directs students toward investigation, analysis, and reflection.

The need to strengthen students' reasoning and information-evaluation skills is also reflected in the broader educational context. The Programme for International Student Assessment (PISA) indicates that scientific literacy remains a challenge for Indonesian students [3]. Although PISA does not directly assess critical thinking or digital literacy as independent constructs, its framework emphasizes competencies such as scientific reasoning, interpretation of evidence, evaluation of information, and the application of scientific knowledge to contextual problems. These competencies conceptually overlap with important elements of critical thinking. At the same time, the increasing use of digital information in education means that scientific reasoning must often be performed in environments where students encounter multiple sources, representations, and forms of digital content. Consequently, improving physics learning requires instructional approaches that not only help students understand concepts but also provide opportunities to evaluate evidence, interpret digital information, and construct conclusions based on scientific reasoning.

This broader challenge was also evident in the local context of the present study. Initial observations conducted in April 2026 in Grade 10 at SMAN 5 Mataram showed that physics instruction was still largely dominated by lecture-based teaching and made

relatively limited use of digital learning media. Based on an interview with the physics teacher, virtual simulations such as PhET had not been routinely incorporated into classroom activities. As a result, students had limited opportunities to explore physics concepts through interactive experimentation. Students also continued to experience difficulty visualizing abstract concepts, particularly in the topic of Work and Energy. An initial diagnostic test indicated that students' critical-thinking ability was in the low category, while the digital-literacy questionnaire showed that some students experienced difficulty evaluating the validity of digital information used during learning. These findings indicate a gap between the competencies expected in twenty-first-century education and the learning experiences available to students. They also highlight the need for instructional materials that systematically integrate scientific inquiry with meaningful use of digital technology.

A physics module based on a PhET-assisted contextual inquiry approach offers a potential response to this need. A contextual approach can connect physics concepts with phenomena that students encounter in everyday life, allowing learning to begin with situations that are meaningful and recognizable. These contextual problems can then be investigated through inquiry activities in which students identify relevant information, formulate questions or hypotheses, explore variables, analyze evidence, and develop conclusions. PhET simulations can support this process by providing a virtual experimental environment in which students can manipulate variables and observe the consequences of those changes directly. When these elements are integrated into a structured module, students can move through a sequence of learning activities that connects real-world phenomena, scientific investigation, digital interaction, and evidence-based reasoning. Such a design is expected to support conceptual construction while simultaneously providing opportunities to access, interpret, use, and evaluate digital information.

Previous studies have provided evidence supporting several components of this approach. Inquiry-based modules and worksheets assisted by PhET have been reported to support learning processes and the development of critical-thinking skills [7], [10], [11], [14], [18]. These studies demonstrate the potential of inquiry and digital simulation to create more active learning environments in physics. Research has also highlighted the relationship between digital literacy and critical thinking in physics education [15], suggesting that the ability to engage critically with digital information may be connected with broader reasoning competencies. However, previous studies have generally emphasized individual components, such as inquiry learning, PhET simulations, critical thinking, or digital literacy. Studies that simultaneously integrate contextual problems, structured inquiry stages, PhET simulations, and explicit digital-literacy activities within a single physics module remain relatively limited. Likewise, relatively few studies have examined changes in critical thinking and digital literacy simultaneously

within the same module-development framework. This limitation represents an important research gap.

Conceptually, the proposed module addresses this gap by organizing learning around authentic contextual problems followed by structured inquiry. Students are guided to formulate hypotheses, manipulate variables using PhET simulations, observe patterns, analyze virtual-experiment results, compare evidence with real-world phenomena, and draw scientifically justified conclusions. At the same time, students interact with digital resources by accessing simulations, interpreting digital representations, and evaluating information used during investigations. This sequence allows critical thinking and digital literacy to be developed through related learning activities rather than as separate instructional objectives. Students are expected to practice analysis when examining relationships among variables, evaluation when judging information and evidence, inference when drawing conclusions from experimental data, and explanation when constructing scientific arguments. Simultaneously, they practice accessing, understanding, using, and evaluating information in a digital learning environment.

The novelty of this study therefore lies not simply in the use of PhET simulations, but in the explicit integration of a contextual approach, inquiry stages, PhET-based virtual experimentation, and digital-literacy activities within one systematically designed physics module. Students are not merely instructed to operate a simulation as a visualization tool. Instead, they are guided to connect simulation results with contextual phenomena, evaluate digital information, construct arguments based on virtual-experiment data, and reflect on how digital information is used during the learning process. This integrated design is intended to position technology as part of scientific reasoning rather than as an additional instructional medium.

Based on these considerations, this study aimed to develop a physics module on Work and Energy based on a PhET-assisted contextual inquiry approach; analyze the validity and practicality of the developed module; and analyze changes in students' critical thinking and digital literacy following the module's limited implementation. At the implementation stage, the operational hypothesis was that students' critical-thinking and digital-literacy scores would differ between the pretest and posttest measurements.

RESEARCH METHODS

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of five sequential stages: Analysis, Design, Development, Implementation, and Evaluation [8], [9]. The ADDIE model was selected because it provides a systematic framework for developing instructional products and allows continuous evaluation and revision throughout the development process.

The study consisted of two complementary components. The first component focused on the

development and validation of a physics learning module integrating a contextual inquiry approach with Physics Education Technology (PhET) simulations. The second component involved a limited implementation of the developed module to examine its practicality and to describe changes in students' critical-thinking and digital-literacy scores.

During the implementation stage, a one-group pretest-posttest design was employed. In this design, the same group of students was assessed before and after learning with the developed module. The design can be represented as follows:

$$O_1 \rightarrow X \rightarrow O_2$$

Note:

O_1 = pretest measurement of critical thinking and digital literacy;

X = learning using the PhET-assisted contextual inquiry physics module; and

O_2 = posttest measurement of critical thinking and digital literacy.

Participants and Research Setting

The study was conducted at SMAN 5 Mataram, West Nusa Tenggara, Indonesia, during the second semester of the 2025/2026 academic year. The limited implementation involved 31 Grade 10 students from class X. Class X was selected purposively based on the physics teacher's recommendation, taking into consideration the characteristics of the class, compatibility with the instructional schedule, and the feasibility of implementing the developed module. After the class had been selected, all 31 students participated in the complete research procedure, and no missing data were recorded during the implementation.

Most students had access to Android-based smartphones and internet connectivity. However, prior to the study, they had not routinely used PhET simulations as part of their physics learning activities. This characteristic was considered relevant because the developed module required students to interact directly with digital simulations during inquiry activities.

Product validation involved three expert validators in Physics Education with expertise related to physics content, instructional-material design, and learning. The validators assessed the quality of the module and research instruments before the module was implemented with students.

ADDIE Development Procedure

The development procedure followed the five stages of the ADDIE model, as illustrated in Figure 1.

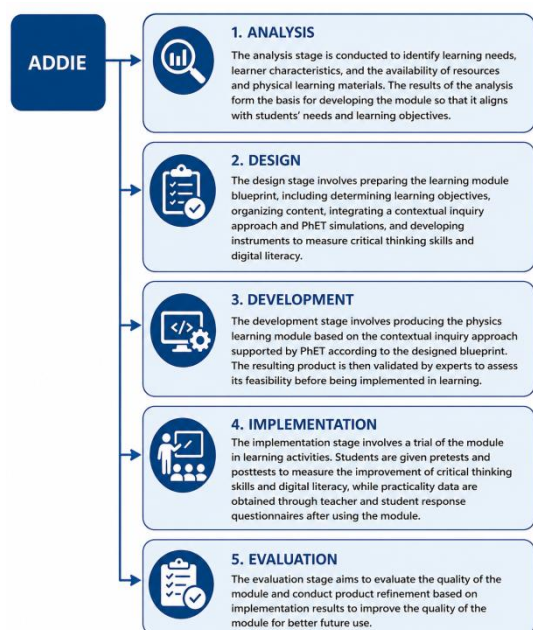


Figure 1. Stages of the ADDIE Development Model

Analysis

The analysis stage was conducted to identify the learning needs and conditions that served as the basis for module development. Data were obtained through classroom observations, an interview with the physics teacher, and analysis of instructional documents.

The needs analysis focused on student characteristics, difficulties in learning Work and Energy, the availability of instructional materials, teacher readiness, and access to digital devices and internet facilities. The analysis showed that physics learning was still predominantly lecture-based and that the use of digital learning media was relatively limited. Students also experienced difficulties understanding abstract concepts related to Work and Energy. At the same time, the availability of digital devices and internet access at the school provided adequate conditions for integrating PhET simulations into physics instruction.

Design

At the design stage, the structure and instructional sequence of the module were prepared based on the results of the needs analysis. The module was designed to integrate contextual problems, inquiry activities, and PhET simulations within a systematic learning sequence.

The module design included learning outcomes, learning objectives, Work and Energy content, contextual problems, inquiry stages, PhET-based virtual experiments, critical-thinking exercises, digital-literacy activities, reflection activities, and learning evaluation. Research-instrument grids, an evaluation plan, and a storyboard for the module interface were also prepared during this stage.

The inquiry activities were designed to guide students from contextual problem identification toward hypothesis formulation, virtual experimentation, data analysis, evaluation of evidence, and conclusion drawing.

Development

During the development stage, the initial design was transformed into a prototype of the physics module. The prototype was subsequently reviewed and validated by three expert validators.

Validation covered four major aspects: **content** feasibility, presentation, language, and graphical design. The validators also reviewed the suitability of the learning activities, instructions for using PhET simulations, contextual problems, and assessment components.

Comments and recommendations from the validators were used as the basis for revising the prototype. Revisions included improvements to the wording of learning objectives, instructional explanations, illustrations, PhET-use instructions, and module layout. The revised product was then prepared for limited classroom implementation.

Implementation

The implementation stage was conducted with 31 students in class X-10 over eight instructional meetings, with each meeting allocated 2×45 minutes.

Before the learning activities began, students completed a critical-thinking pretest and an initial digital-literacy assessment. They then participated in group-based learning using the PhET-assisted contextual inquiry physics module under the guidance of the physics teacher.

During the learning process, students worked with contextual problems, formulated hypotheses, performed virtual experiments using PhET simulations, manipulated relevant physical variables, analyzed experimental results, and drew evidence-based conclusions.

After all learning activities had been completed, students took the critical-thinking posttest and completed the digital-literacy assessment. Student-response questionnaires were also administered to obtain information regarding the practicality of the developed module.

Evaluation

Evaluation was conducted formatively throughout the ADDIE development process. Feedback from validators, the teacher, and students was used to identify aspects of the module that required improvement.

The evaluation focused on the accuracy and organization of the content, clarity of instructions, visual presentation, accessibility of PhET simulations, language, and usability of the learning activities. The results of the formative evaluation were used to refine the module until a final version suitable for the limited implementation context was obtained.

Research Instruments

Four main types of instruments were used in this study: expert-validation sheets, practicality instruments, a critical-thinking test, and a digital-literacy questionnaire. The expert-validation sheet was used to assess the quality of the developed product in terms of content feasibility, presentation, language, and graphical

design. The validation criteria were adapted from criteria previously used in instructional-tool development [19].

Module practicality was assessed using three sources of information: lesson-implementation observations, teacher responses, and student responses. These instruments were used to determine the extent to which the module could be implemented and used during the learning process.

Critical-thinking ability was measured using five essay questions. The questions covered the indicators of analysis, evaluation, interpretation, inference, and explanation. Student responses were assessed using the same scoring rubric to ensure consistency in the evaluation process. Digital literacy was measured using a questionnaire based on four indicators: the ability to access, understand, use, and evaluate digital information. The questionnaire employed a four-point Likert scale.

Before implementation, the instruments were reviewed by expert validators to assess their content relevance, construction, and language suitability.

Data Analysis

Data analysis included product validity, practicality, instrument reliability, normalized gain, normality, and differences between pretest and posttest scores.

Product Validity and Practicality

The validity and practicality scores were converted into percentages using Equation:

$$P = \frac{\sum S_o}{\sum S_m} \times 100\%$$

Where P is the percentage score, S_o is the obtained score, and S_m is the maximum possible score. The validity percentages were interpreted as follows: 81–100% = highly valid, 61–80% = valid, 41–60% = moderately valid, 21–40% = less valid, and 0–20% = invalid. Practicality was interpreted from the percentage scores obtained from lesson implementation, teacher responses, and student responses.

Normalized Gain Analysis

Changes in students' critical-thinking and digital-literacy scores were analyzed using normalized gain (N-Gain), calculated using Equation:

$$g = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{max}} - S_{\text{pre}}}$$

where g is the normalized gain, S_{post} is the posttest score, S_{pre} is the pretest score, and S_{max} is the maximum possible score. The N-Gain values were classified as high when $g \geq 0.70$, moderate when $0.30 \leq g < 0.70$, and low when $g < 0.30$.

Reliability Analysis

The internal consistency of the instrument was examined using Cronbach's alpha, as expressed in Equation:

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^k \sigma_i^2}{\sigma_T^2} \right)$$

where α is Cronbach's alpha coefficient, k is the number of items, σ_i^2 is the variance of item i , and σ_T^2 is the variance of the total score. A Cronbach's alpha coefficient of approximately 0.70 or higher was considered to indicate adequate internal consistency. The essay-based critical-thinking responses were assessed using the same scoring rubric across all students to maintain consistency in scoring.

Normality Test

The normality of the pretest and posttest scores was examined using the Shapiro-Wilk test because the study involved fewer than 50 participants. The level of significance was set at $\alpha = 0.05$. Data were considered normally distributed when $p > 0.05$ and non-normally distributed when $p \leq 0.05$. Because at least one distribution within each pretest-posttest pair did not satisfy the normality assumption, a nonparametric paired-sample test was used for the subsequent analysis.

Wilcoxon Signed-Rank Test

Differences between pretest and posttest scores for critical thinking and digital literacy were analyzed using the Wilcoxon Signed-Rank Test. This nonparametric test was selected because the paired data did not fully satisfy the normality assumption. The null and alternative hypotheses were formulated as follows:

$$H_0: \tilde{D} = 0$$

$$H_1: \tilde{D} \neq 0$$

where $\tilde{D}$ denotes the median of the paired differences between posttest and pretest scores. The null hypothesis was rejected when $p < 0.05$ and was not rejected when $p \geq 0.05$. All inferential statistical analyses were performed using SPSS at a significance level of $\alpha = 0.05$. Because the study employed a one-group pretest-posttest design without a comparison group, statistically significant differences were interpreted as changes following module implementation rather than as definitive evidence of a causal effect.

RESULT AND DISCUSSION

The product developed in this study was a physics module on Work and Energy based on a contextual inquiry approach assisted by PhET simulations. The module included a cover, instructions for use, learning outcomes and objectives, a concept map, learning content, contextual inquiry activities, virtual-experiment activities, student worksheets (LKPD), exercises, reflection, and learning evaluation. This structure was designed to enable students to construct concepts through guided investigation [10].

The development results are presented in terms of product characteristics, validity, practicality, changes

in critical thinking and digital literacy, and statistical-test results. Because implementation used a one-group pretest-posttest design, the inferential results were used to describe score changes in the trial group rather than to establish a causal effect of the module.

Each learning activity began with a contextual phenomenon, followed by inquiry stages, PhET-based exploration, data analysis, conclusion drawing, and reflection. This structure connected physics concepts with students' everyday experiences while providing

opportunities to use digital evidence in reasoning.

The module was equipped with QR codes and links that directed students to PhET simulations. These features allowed students to access virtual experiments, manipulate variables, and observe relationships among physical quantities independently or in groups. The use of QR codes in learning materials can facilitate access to digital resources [6], while PhET supports conceptual exploration through interactive simulations [7], [20].

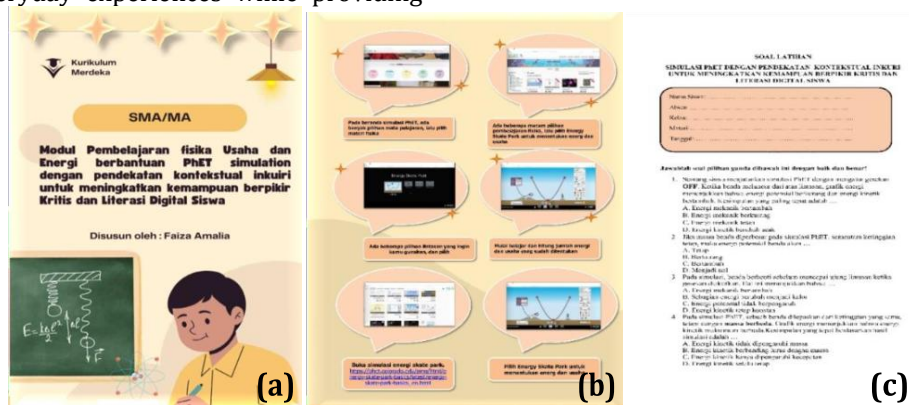


Figure 2. (a) Cover of the Learning Module; (b) Integration of PhET Simulations in the Module; (c) Contextual Inquiry-Based Student Worksheet (LKPD)

Validity Results

Product validity was assessed by three validators with expertise in physics content,

instructional materials, and learning. The assessment covered content feasibility, presentation, language, and graphical design.

Table 1. Summary of Expert Validation Results

Component	V1	V2	V3	Average	Category
Module	86	90	90.3	88.77	Highly valid
Student Worksheet (LKPD)	90	87.5	95	90.83	Highly valid
Lesson Implementation	90	90	87.5	89.17	Highly valid
Teacher Response	92.5	86	87.5	88.67	Highly valid
Student Response	87.5	90	92.5	90	Highly valid
Critical-Thinking Test	90	90	95	91.67	Highly valid
Digital-Literacy Test	87	87	92.5	88.83	Highly valid

In addition to assigning scores, the validators recommended refining the wording of learning objectives, adjusting illustrations, simplifying PhET instructions, and improving the layout of several module components. These recommendations were used to revise the prototype before implementation, meaning that the validation process not only produced feasibility scores but also guided product improvement.

Based on the three validator scores presented in Table 1, the learning module obtained an average score of 88.8% and was categorized as highly valid. This result indicates that the module met the feasibility criteria for the aspects assessed in this development context.

The high validity score reflects the alignment

among the learning objectives, Work and Energy content, inquiry stages, and the integration of PhET simulations as a means of conceptual exploration. Such alignment is important to ensure that technology does not stand alone but supports the intended learning activities. This finding is consistent with research on digital-technology teaching materials that emphasizes the importance of construct quality and presentation in supporting learning [16].

Practicality Results

Module practicality was measured through lesson-implementation observations, teacher responses, and student responses.

Table 3. Summary of Module Practicality Results

Practicality Component	Likert Scale	Score (%)	Category
Lesson Implementation	4	92.5	Highly practical
Teacher Response	4	90	Highly practical
Student Response	3	75.5	Practical

The practicality test showed a lesson-implementation score of 92.5%, a teacher-response score of 90%, and a student-response score of 75.5%, with an overall average of 86%. The high lesson-implementation and teacher-response scores indicate that the module could be used according to the designed learning sequence, whereas the lower student-response score suggests that students' user experience was not as strong as the teacher's evaluation and the observed implementation.

During implementation, the teacher was able to follow the prescribed learning sequence, and students were able to complete the activities independently and in groups. The instructions, sequence of inquiry activities, and access to PhET through links or QR codes supported the implementation of the learning process.

The practicality of the module was also supported by the role of PhET simulations in visualizing concepts and providing opportunities for exploration. This

finding is consistent with research reporting that PhET-assisted e-modules can be used practically and can promote student engagement [12]. Nevertheless, the student-response score should be considered separately from the overall mean so that aspects requiring further refinement are not obscured by the high lesson-implementation and teacher-response scores.

The student-response score of 75.5% indicates that the user experience of the module still requires refinement. Classroom observations during implementation showed that some students needed time to understand the instructions and adapt to inquiry activities and PhET simulations because they had not previously used this type of digital medium in physics learning. This finding suggests that product practicality is influenced not only by module design but also by students' prior experience with learning technologies.

Changes in Critical Thinking and Digital Literacy

Table 4. N-Gain Results for Students' Critical Thinking and Digital Literacy

Variable	Pretest	Posttest	N-Gain	Category
Critical Thinking	48.2	82.6	0.74	High
Digital Literacy	46.5	88.9	0.79	High

N-Gain was calculated using the maximum score specified for each instrument. As shown in Table 4, the N-Gain was 0.74 for critical thinking and 0.79 for digital literacy; both values were categorized as high according to the criteria used in this study.

The change in critical-thinking performance can be associated with the inquiry activities, which required students to identify problems, formulate hypotheses, manipulate variables, analyze data, evaluate results, and draw conclusions. These activities directly provided practice in analysis, evaluation, inference, and explanation. The finding is consistent with research reporting a positive contribution of inquiry learning to critical thinking [13] and with studies of PhET-assisted guided inquiry that have reported positive outcomes for critical-thinking skills [14].

Changes in critical thinking and digital literacy can also be understood as two processes that overlap within the module design. When using PhET, students interacted with digital information while evaluating relationships among variables, interpreting representations, and drawing evidence-based conclusions. The conceptual relationship between digital literacy and critical thinking in physics education has also been highlighted in previous research [15]. However, the present study did not statistically analyze the relationship between the two variables; therefore, the findings are not interpreted as evidence of a causal relationship between them.

For digital literacy, learning activities extended beyond simply operating the simulation. Students accessed digital resources, used the simulation interface, interpreted graphs and representations, compared virtual-experiment results, and evaluated information used during the investigation. These activities correspond to the indicators of accessing, understanding, using, and evaluating digital information measured in this study.

These findings extend previous research on the use of inquiry and PhET in physics learning [11]. Research using a PhET-assisted problem-based learning model has also reported that simulations can support active learning when embedded in a problem-solving process [17]. Compared with those studies, the module developed here integrates contextual problems, inquiry stages, PhET use, and digital-literacy activities within a single learning sequence.

The higher N-Gain for digital literacy than for critical thinking indicates that the changes in the two variables were not identical. Digital activities were performed directly and repeatedly through QR-code use, simulation access, variable manipulation, and interpretation of virtual-experiment results. In contrast, critical thinking involves complex cognitive processes that require sustained practice. The difference in N-Gain values is descriptive and is not used to conclude that the module had a statistically greater effect on one variable than on the other.

The characteristics of the Work and Energy topic also support the use of simulations. Relationships among force, displacement, work, kinetic energy, and potential energy can be difficult to understand when presented only through verbal explanations or equations. PhET allows students to manipulate variables and observe changes in real time, thereby generating data that can be analyzed and used to draw conclusions.

Overall, the limited implementation showed increases in critical-thinking and digital-literacy scores after learning with the module. These findings provide preliminary evidence of the module's potential as a learning resource that integrates physics inquiry with the use of digital information.

The findings must nevertheless be interpreted in light of the one-group pretest-posttest design. Without a comparison group, the score changes cannot be attributed entirely to the use of the module. Accordingly,

effectiveness in this study is positioned as potential effectiveness within a limited-trial context.

Theoretically, the module design is consistent with a constructivist perspective in which students actively construct knowledge through interaction with problems, data, and the learning environment. The integration of authentic contexts, inquiry, and digital technology indicates that physics learning can be designed to develop conceptual understanding while

also providing opportunities to practice higher-order thinking and digital literacy.

Reliability and Normality Results

The reliability analysis reported in Table 5 yielded a Cronbach's Alpha of 0.717 for 35 analyzed items. Because the coefficient exceeded 0.70, the analyzed item set demonstrated adequate internal consistency.

Table 5. Reliability Test Results

Analyzed Items	Cronbach's Alpha	N
All analyzed items	0.717	35

The Shapiro-Wilk test showed significance values of 0.008 for the critical-thinking and digital-literacy pretest scores, while the respective posttest values were 0.061 and 0.063. Thus, at least one score distribution for each variable did not satisfy the normality assumption at the 0.05 level.

The internal-consistency analysis of the 35 analyzed items yielded a Cronbach's Alpha of 0.717. The critical-thinking essay test was scored using the same rubric for all student responses to maintain consistency in scoring.

Table 6. Normality Test Results

Tests of Normality Shapiro-Wilk			
Variable	Statistic	N	Sig.
Critical Thinking Pretest	0.901	31	0.008
Critical Thinking Posttest	0.935	31	0.061
Digital Literacy Pretest	0.901	31	0.008
Digital Literacy Posttest	0.936	31	0.063

Because at least one score distribution for each variable was non-normal, differences between pretest and posttest scores were analyzed using the Wilcoxon Signed-Rank Test. The results showed $p < 0.001$ for both

critical thinking and digital literacy, indicating significant differences between measurements before and after module implementation in the trial group.

Table 7. Wilcoxon Signed-Rank Test Results

Variable	p-value	Interpretation
Critical Thinking	< 0.001	Significant
Digital Literacy	< 0.001	Significant

Taken together, the validity, practicality, N-Gain, and pretest-posttest comparison results indicate that the PhET-assisted contextual inquiry module can be considered a promising alternative learning resource for twenty-first-century physics education. The main strength of the product lies in integrating inquiry activities with the use of digital resources rather than using simulations merely as visualization tools.

However, the statistical significance of the pretest-posttest differences does not by itself demonstrate that the module was the sole cause of the observed changes. The findings are more appropriately positioned as preliminary evidence from a limited trial that should be confirmed in future studies using a comparison group and effect-size analysis.

Research Limitations

This study has several limitations. First, implementation used a one-group pretest-posttest design without a control group; therefore, causal inference cannot be made. Second, the study involved only one class and one physics topic, Work and Energy, which limits the generalizability of the findings. Third, digital literacy was measured using a self-report instrument that more closely reflects students' perceptions than their actual performance. Fourth, the implementation period was relatively short, and students differed in their prior ability to use digital

devices. Future studies should include a comparison group, a larger sample, performance-based measures of digital literacy, and effect-size reporting to strengthen the evidence regarding module effectiveness.

CONCLUSION

This study developed a physics learning module on Work and Energy that integrates a contextual inquiry approach with Physics Education Technology (PhET) simulations. The module was designed to support students in exploring physics concepts through contextual problems, inquiry activities, virtual experimentation, and the use of digital information. Based on expert validation, the developed module demonstrated a high level of validity, indicating that its content, presentation, language, and graphical design were appropriate for use in physics learning. The limited implementation also showed that the module had good practicality, suggesting that it could be applied in classroom learning with support from teachers and students.

The implementation of the module with 31 Grade 10 students showed positive changes in both critical-thinking and digital-literacy scores. The mean critical-thinking score increased from 48.2 on the pretest to 82.6 on the posttest, while the mean digital-literacy score increased from 46.5 to 88.9. The normalized gain

(N-Gain) values were 0.74 for critical thinking and 0.79 for digital literacy, placing both variables in the high improvement category. In addition, the Wilcoxon Signed-Rank Test showed statistically significant differences between pretest and posttest scores for critical thinking and digital literacy, with $p < 0.001$ for both variables. These findings indicate that the module has the potential to support the development of students' critical-thinking and digital-literacy competencies during physics learning.

The integration of contextual problems, inquiry stages, and PhET simulations provided students with opportunities to formulate hypotheses, manipulate variables, analyze virtual-experiment results, interpret evidence, and draw conclusions. At the same time, the learning activities required students to access, understand, use, and evaluate digital information. Therefore, the module has the potential to serve not only as a resource for conceptual learning in physics but also as a learning environment that encourages scientific reasoning and responsible engagement with digital information.

ACKNOWLEDGMENTS

The authors would to express their sincere gratitude to the academic supervisors for their guidance, constructive feedback, and continuous support throughout the research and manuscript preparation process. The authors also thank the expert validators, physics teacher, and students of SMAN 5 Mataram who participated in this study and contributed to the implementation and evaluation of the developed module. Appreciation is also extended to the Physics Education Study Program, Universitas Pendidikan Mandalika, for its academic and institutional support.

REFERENCES

- [1] R. Nurhidayati and A. Thaufani, "Mendorong literasi digital guru melalui manajemen pendidikan," *Jurnal Manajemen Pendidikan*, vol. 10, no. 3, pp. 1705–1713, 2025, doi: 10.34125/jmp.v10i3.654.
- [2] A. Hariyono, "Digital literacy and educational transformation in the twenty-first century," *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 29, no. 1, pp. 12–20, 2023.
- [3] A. Z. Alfaruqi and Nurwahidah, "Reflection on Indonesia's PISA scores and the 2024 Madrasah teacher competency assessment results," *Jurnal Pendidikan IPS*, vol. 15, no. 1, pp. 11–19, 2025, doi: 10.37630/jpi.v15i1.2559.
- [4] A. S. A. Wahyuni and S. Kijkuakul, "Digitally integrated project-based contextual physics resources," *Jurnal Pendidikan IPA Indonesia*, vol. 14, no. 4, pp. 643–653, 2025, doi: 10.15294/jpii.v14i4.31581.
- [5] L. Herayanti, Fuaddunnazmi, and B. R. A. Safitri, "Ethnoscience-based learning supported by LMS," *Jurnal Pendidikan Fisika dan Teknologi*, vol. 11, no. 1a, pp. 117–130, 2025, doi: 10.29303/jpft.v11i1a.9773.
- [6] N. Arifah and N. Azis, "Pengembangan modul pembelajaran fisika berbasis kontekstual terintegrasi QR code," *Indonesian Journal of Natural Science Education*, vol. 5, no. 2, pp. 24–31, 2022, doi: 10.31002/ijnse.v5i2.2620.
- [7] S. I. Kholida *et al.*, "Inquiry-based physics learning module with PhET assistance," *Jurnal IPA dan Pembelajaran IPA*, vol. 9, no. 3, pp. 1003–1019, 2025, doi: 10.24815/jipi.v9i3.48745.
- [8] A. Rustandi and Rismayanti, "Penerapan model ADDIE dalam pengembangan media pembelajaran," *Jurnal Fasikom*, vol. 11, no. 2, pp. 57–60, 2021.
- [9] M. A. Adeoye *et al.*, "Revolutionizing education: Unleashing the power of the ADDIE model for effective teaching and learning," *Jurnal Pendidikan Indonesia*, vol. 13, no. 1, pp. 202–209, 2024, doi: 10.23887/jpiundiksha.v13i1.68624.
- [10] F. N. Amini, E. Roektingroem, and I. Wilujeng, "Development of student worksheet based on guided inquiry assisted by PhET simulation," *Journal of Science Education Research*, vol. 6, no. 1, pp. 46–50, 2022, doi: 10.21831/jsr.v6i1.48244.
- [11] P. Aswirna, M. Roza, and R. Aldania, "Application of LKPD based on guided inquiry model assisted by PhET simulation," *Journal of Learning and Technology in Physics*, vol. 2, no. 2, pp. 46–53, 2024, doi: 10.24114/jltp.v2i2.56676.
- [12] Fitriyawany, "Uji kepraktisan pengembangan bahan ajar fisika berbentuk e-modul berbasis TPACK dan PhET simulation," *Desultana: Journal Education and Social Science*, vol. 3, no. 1, pp. 31–40, 2025, doi: 10.69548/d-jess.v3i1.42.
- [13] L. Syahgiah, A. M. Zan, and Asrizal, "Effects of inquiry learning on students' science process skills and critical thinking," *Journal of Innovative Physics Teaching*, vol. 1, no. 1, pp. 16–28, 2023, doi: 10.24036/jipt/vol1-iss1/9.
- [14] S. R. Fitriani *et al.*, "The effect of the guided inquiry model assisted by PhET media on students' critical thinking skills," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 6, pp. 3527–3532, 2024, doi: 10.29303/jppipa.v10i6.4852.
- [15] A. Mufidah and H. Putranta, "Identification of digital literacy skills on critical thinking of physics education students," *Jurnal Cerdik*, vol. 4, no. 1, pp. 46–62, 2024, doi: 10.21776/ub.jcerdik.2024.004.01.06.
- [16] R. T. Sukmanjaya *et al.*, "EFA analysis of digital technology teaching materials," *JPPS*, vol. 14, no. 1, pp. 23–38, 2024, doi: 10.26740/jpps.v14n1.p23-38.
- [17] F. Mustikazahra, H. Novia, and L. Aviyanti, "Application of PhET simulation-assisted problem-based learning model," *Journal of Educational Sciences*, vol. 9, no. 4, pp. 1742–1752, 2025, doi: 10.31258/jes.9.4.p.1742-1752.
- [18] A. Wandira *et al.*, "Pengembangan modul pembelajaran fisika berbantuan PhET berbasis inkuiri," *CAHAYA: Journal of Research on Science Education*, vol. 1, no. 1, pp. 25–41, 2023, doi: 10.70115/cahaya.v1i1.41.

- [19] A. Azmi, J. Wahab, and M. M. Jufri, "Learning tools with inquiry integrated of character education," *Jurnal Pendidikan Fisika*, vol. 8, no. 1, pp. 17–24, 2020.
- [20] M. I. Tanzillal, E. Hertanti, and I. P. Suwarna, "Pengaruh PhET interactive simulations terhadap pemahaman konsep," *Jurnal Pendidikan Matematika dan Sains*, vol. 14, no. 1, pp. 121–130, 2026, doi: 10.21831/jpms.v14i1.91208.